

How do you spell VSWR?

By Harold Kinley, CET

Of course, there is only one way to spell VSWR, but there are many ways to represent antenna (or other RF load or source) mismatches using different

measuring units.

For example, occasionally you will see the terms *return loss*, *reflection coefficient*, *percent reflected power* and *reflected-to-forward power ratio*. It is enough to confuse Confucius!

But do not despair. There is a way to

convert among the various units without using calculus.

► **VSWR**—Probably the most widely used and best understood measuring unit used by radio communications technicians is voltage standing wave ratio (VSWR).

When a manufacturer specifies that a certain antenna operates over a certain frequency range at a VSWR of 1.5:1 or better (less), we immediately know that this is a good match—the system will operate efficiently with minimal wasted power.

► **Return loss**—When the forward power on a transmission line equals 100W and the reflected power equals 25W, the return loss is determined by the following formula:

R_L

$$= 10 \log(P_F/P_R)$$

$$= 10 \log(100/25)$$

$$= 10 \log(4)$$

$$= 10 \times 0.602$$

$$= 6.02 \text{ dB}$$

where

R_L = return loss in decibels

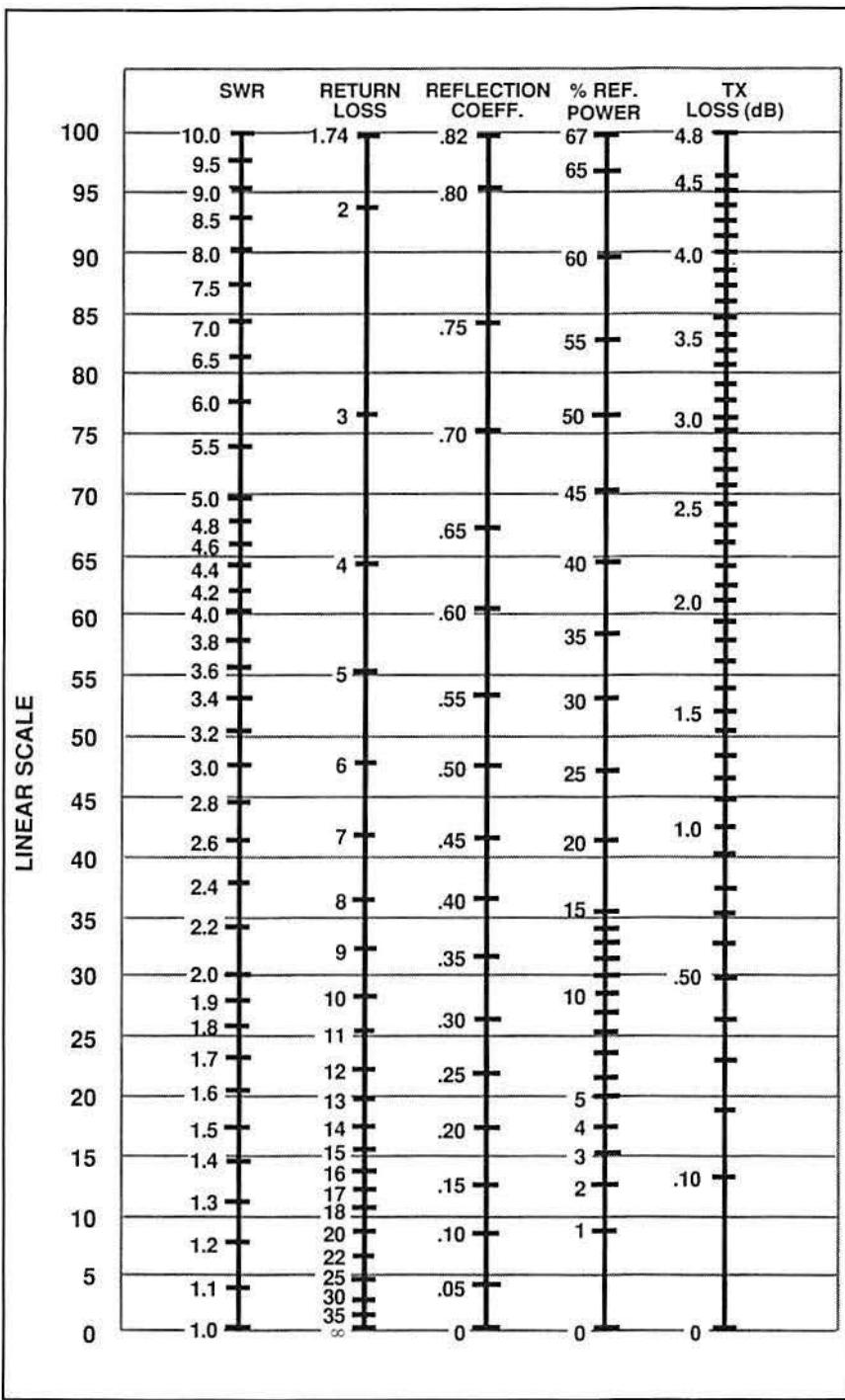
P_F = forward power in watts

P_R = reflected power in watts

Because of transmission line loss, the VSWR at the antenna is worse than what is measured at the transmitter, and the same difference applies for every unit of measure.

It is easy to convert return loss at the transmitter to return loss at the antenna because the transmission line loss usually is stated in terms of decibels per 100 feet (dB/100ft.).

For example, if the line loss is 2dB and the return loss at the transmitter is (continued on page 58)



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Technically speaking

(continued from page 8)

10dB, then the return loss at the antenna is:

$$\begin{aligned} R_L &= 2(L_L) \\ &= 10 - 2(2) \\ &= 6 \text{dB} \end{aligned}$$

where

R_L = return loss in decibels at the transmitter

L_L = transmission line loss

It is necessary to multiply the line loss by a factor of 2 because both the forward power and the reflected power are attenuated by the line loss. In this example, the forward power is 2dB lower at the antenna, and the reflected power is 2dB higher at the antenna.

► **Reflection coefficient**—Simply stated, reflection coefficient is the ratio of

voltage of the *incident* wave to voltage of the *reflected* wave.

Because voltage is proportional to the square root of the power, reflection can be defined as $\sqrt{(P_R)}/\sqrt{(P_F)}$ or simply $\sqrt{(P_R/P_F)}$.

For example, if the forward power is 100W and the reflected power is 25W, then the reflection coefficient Γ is calculated as follows:

$$\begin{aligned} \Gamma &= \sqrt{(25/100)} \\ &= \sqrt{(0.25)} \\ &= 0.5 \end{aligned}$$

► **Reflected-to-forward power ratio**—

The reflected-to-forward power ratio unit of measure probably is the most familiar to land mobile radio technicians because they favor the use of an in-line directional wattmeter to measure forward and reflected power on the trans-

mission line.

It is simple, then, just to compare the reflected power reading with the forward power reading to get a quick mental picture of the degree of mismatch on the line.

For example, if the forward power is 100W and the reflected power is 25W, then the ratio (reflected-to-forward) is 0.25. Notice that this figure is the *square of the reflection coefficient* that was obtained using the same reflected and forward power measurements.

► **Percent reflected power**—The percent reflected power figure is obtained by multiplying the reflected-to-forward power ratio by 100.

For example, a ratio of 0.25 equals 25% reflected power.

Transmission loss—Transmission loss is the actual loss in the transmitted signal resulting from the mismatch.

For example, with 100W of forward power at the antenna and 25W of reflected power, only 75% of the *available power* is transmitted. The transmission loss is:

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Technically speaking

$$\begin{aligned}T_L &= 10 \log(1 - r) \\&= 10 \log(1 - 0.25) \\&= 10 \log(0.75) \\&= 10 \times -0.125 \\&= -1.25 \text{ dB}\end{aligned}$$

Conversion formulae: The following formulae can be used to convert between any of the measuring units discussed.

$$S = \frac{1+\sqrt{r}}{1-\sqrt{r}}$$

$$S = \frac{1+\Gamma}{1-\Gamma}$$

$$S = \frac{1+10^{-(R_L/20)}}{1-10^{-(R_L/20)}}$$

$$r = \left(\frac{S-1}{S+1} \right)^2$$

$$r = \Gamma^2$$

$$r = 10^{-(R_L/10)}$$

$$\Gamma = \sqrt{r}$$

$$\Gamma = \frac{S-1}{S+1}$$

$$\Gamma = 10^{-(R_L/20)}$$

$$R_L = 10 \log \left[\frac{1}{\left(\frac{S-1}{S+1} \right)^2} \right]$$

$$R_L = 10 \log \left(\frac{1}{r} \right)$$

$$R_L = 10 \log \left(\frac{1}{\Gamma^2} \right)$$

$$T_L = 10 \log \left[1 - \left(\frac{S-1}{S+1} \right)^2 \right]$$

$$T_L = 10 \log(1 - \Gamma^2)$$

$$T_L = 10 \log(1 - r)$$

$$R = 100r$$

where

$$S = \text{VSWR}$$

$$\Gamma = \text{reflection coefficient}$$

$$T_L = \text{transmission loss in decibels}$$

$$R_L = \text{return loss in decibels}$$

$$r = \text{reflected-to-forward power ratio}$$

$$R = \text{percent reflected power}$$

Nomograph—The nomograph in Figure 1 on page 8 converts between equivalent units of VSWR, return loss, percent reflected power, reflection coefficient and transmission loss that lie on the same line. At a glance, you can convert from any unit of measure to another.

There are a few advantages that are not so apparent at first glance.

For example, if you know the VSWR at the transmitter and the line loss, you can find the VSWR at the antenna by

using the following example as a guide.

The VSWR at the transmitter is 2.0:1, and the line loss is 2.5dB. Locate 2.0 on the VSWR scale and read the equivalent return loss in decibels on the next scale. It is approximately 9.5dB.

Subtract twice the line loss ($2 \times 2.5 = 5$) from the return loss reading, and move to that point on the return loss scale. This point will be 4.5dB on the return loss scale, which is equivalent to a VSWR of approximately 4:1 at the antenna.

The nomograph can be used to determine the maximum VSWR that can be seen at the transmitter for a given amount of line loss.

For example, suppose the line loss is 3.0dB. Double this figure and move to 6 on the return loss scale. Follow the line out to the VSWR scale, and note that for a 3dB line loss, the maximum VSWR seen at the transmitter is approximately 3.0:1.

The *transmission loss* scale may provide some surprises.

For example, notice that for a VSWR of 3.0:1, the transmission loss is only 1.25dB. It appears, then, that a VSWR of 3.0:1 is not so terrible after all.

Here is the catch: Modern radio transmitters have an automatic power reduction circuit that limits output when a high VSWR is detected. Thus, the practical transmission loss would be much greater for such radios than would be indicated by the nomograph.

For example, if power output is reduced 50% for a VSWR of 3.0:1, this reduction would add 3dB to the *normal* transmission loss to make the practical effect a net 4.25dB transmission loss.

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